

**X-693-72-45**

**PREPRINT**

65833

# **SOME CHARACTERISTICS OF MICROWAVE TYPE IV RADIO BURSTS AND THE ACCELERATION OF SOLAR COSMIC RAYS**

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**FEBRUARY 1972**



**— GODDARD SPACE FLIGHT CENTER —  
GREENBELT, MARYLAND**

(NASA-TM-X-65833) SOME CHARACTERISTICS OF  
MICROWAVE TYPE 4 RADIO BURSTS AND THE  
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Sakurai (NASA) Feb. 1972 10 p CSCL 03B

N72-18798

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(CATEGORY)

SOME CHARACTERISTICS OF MICROWAVE TYPE IV RADIO BURSTS  
AND THE ACCELERATION OF SOLAR COSMIC RAYS

by

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ABSTRACT

This paper discusses the relationships between some characteristics of microwave type IV radio bursts and solar cosmic ray protons of Mev energy. It is shown that the peak flux intensity of those bursts is almost linearly correlated with the Mev proton peak flux observed by satellites near the earth. The rise times of type IV microwave emissions are, however, independent of the proton peak fluxes. Using these results, discussion is given on the acceleration process and duration for both protons and electrons.

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. During May, 1967 through October, 1969, thirty six solar cosmic ray events have been observed by the Explorer 33 and 35 satellites near the earth (Solar Geophysical Data, 1967-1969). Intense emission of type IV radio bursts of microwave frequencies was observed for thirty events among them. As is well known, the generation of solar cosmic rays is generally associated with solar flares which accompany type IV radio bursts of wide band (e.g., Hakura and Goh, 1959; Kundu and Haddock, 1960; Sakurai and Maeda, 1961).

Recently, Castelli, Aarons and Michael (1967, 1968) pointed out that the shape of the peak flux spectra of type IV radio bursts is important in predicting the generation of solar cosmic rays. In this case, the flux intensity of microwave component of the bursts must be much higher than both decimetric and metric intensities. Croom (1970) later showed that the centimeter radio bursts are good indicators of proton events.

In fact, the microwave component of type IV radio bursts is emitted from stationary sources, formed in or near the flare regions, which are independent of the outward

moving radio sources mainly responsible for metric emissions (e.g., Sakurai, 1971). Furthermore, the microwave emissions generally start simultaneously with or immediately after the explosive phase of solar flares (Svestka, 1970; Sakurai, 1971). These facts mean that the electrons responsible for microwave emissions are accelerated during the explosive phase. Since it is known that solar cosmic ray protons and heavier nuclei are also accelerated during this phase (e.g., Ellison, McKenna and Reid, 1961), it seems natural to infer that some characteristics of microwave type IV bursts are certainly related to the acceleration process or some properties of solar cosmic rays.

We have here considered the peak fluxes and rise times of microwave type IV emissions as such characteristics, because the formers generally become maximum a few minutes after the explosive phase and the latters seem to indicate how rapidly the radio events develop in association with solar flares. Furthermore, in case of solar cosmic rays, we have taken up the hourly averaged peak fluxes of solar protons of energy higher than 10 Mev. In reality, if we consider theoretically the diffusion process of solar protons in interplanetary space, it is evident that the

observed peak flux is proportional to the emitted flux of solar protons per unit solid angle at the sun (e.g., Webber, 1964; Feit, 1971). By using those data on microwave type IV bursts and solar cosmic rays, we have investigated correlations of such peak fluxes of solar protons with the peak fluxes and rise times of microwave type IV bursts.

As is well known, the values of the peak fluxes of solar protons are highly dependent on the position of parent flares at the sun. Before analyzing the relations between the proton peak fluxes and the peak fluxes or rise times of microwave type IV bursts, we, therefore, need consider the dependence of the proton peak fluxes on the position of parent flares at the sun. In fact, this dependence is clearly seen as shown in Fig. 1. Especially, on the eastern hemisphere, the peak flux of solar protons ( $> 10$  Mev) tends to decrease as the position of parent flares approaches the east limb at the sun. Since we have known that the peak fluxes of microwave type IV bursts do not show a center-to-limb variation at the sun (Takakura, 1963; Sakurai, 1964), we, however, cannot compare the peak fluxes of solar protons for all observed events with the peak fluxes and rise times of microwave type IV bursts.

As is shown in Fig. 1, the values of the proton peak fluxes are so much scattered in the cases when parent flares took place on the western hemisphere. In this paper, we, therefore, have only considered the solar cosmic ray events which were produced by solar flares on the western hemisphere at the sun.

A relationship between the proton peak fluxes and the peak fluxes of microwave type IV bursts has been first analyzed. The result is shown in Fig. 2. In analyzing this problem, we have used the data on the microwave peak flux intensities at  $\sim 3000$  MHz. Fig. 2 indicates that the proton peak flux is almost linearly proportional to the peak flux of microwave type IV bursts.

Further analysis has been made on a relation between the proton peak fluxes and the rise times of microwave type IV bursts. The result is shown in Fig. 3. This shows that the rise times are not correlated with the peak proton fluxes. It can, therefore, be said that these rise times seem to be controlled by some factors, though still unknown, independent of the acceleration process of solar cosmic ray protons and electrons. Whereas the result as shown in Fig. 2 seems to indicate that the number of accelerated electrons responsible for microwave type IV bursts is

roughly proportional to that of solar protons ( $> 10$  Mev), although we do not know as yet what process works on the production and ejection of these particles. The mechanism and duration of the acceleration seem to be almost the same for both protons and electrons. If this is not the case, it seems difficult to obtain an almost linear correlation between the proton peak fluxes and the peak flux intensities of the microwave type IV emissions.

In conclusion, we would say that the peak fluxes of microwave type IV bursts are considered as good indicators of solar cosmic ray generation. Furthermore, a proportional relation between the peak fluxes of solar protons and of microwave type IV bursts (Fig. 2) indicates that the acceleration processes of both protons and electrons are closely related each other: these protons and electrons may be energized through the same acceleration mechanism during the explosive phase of solar flares.

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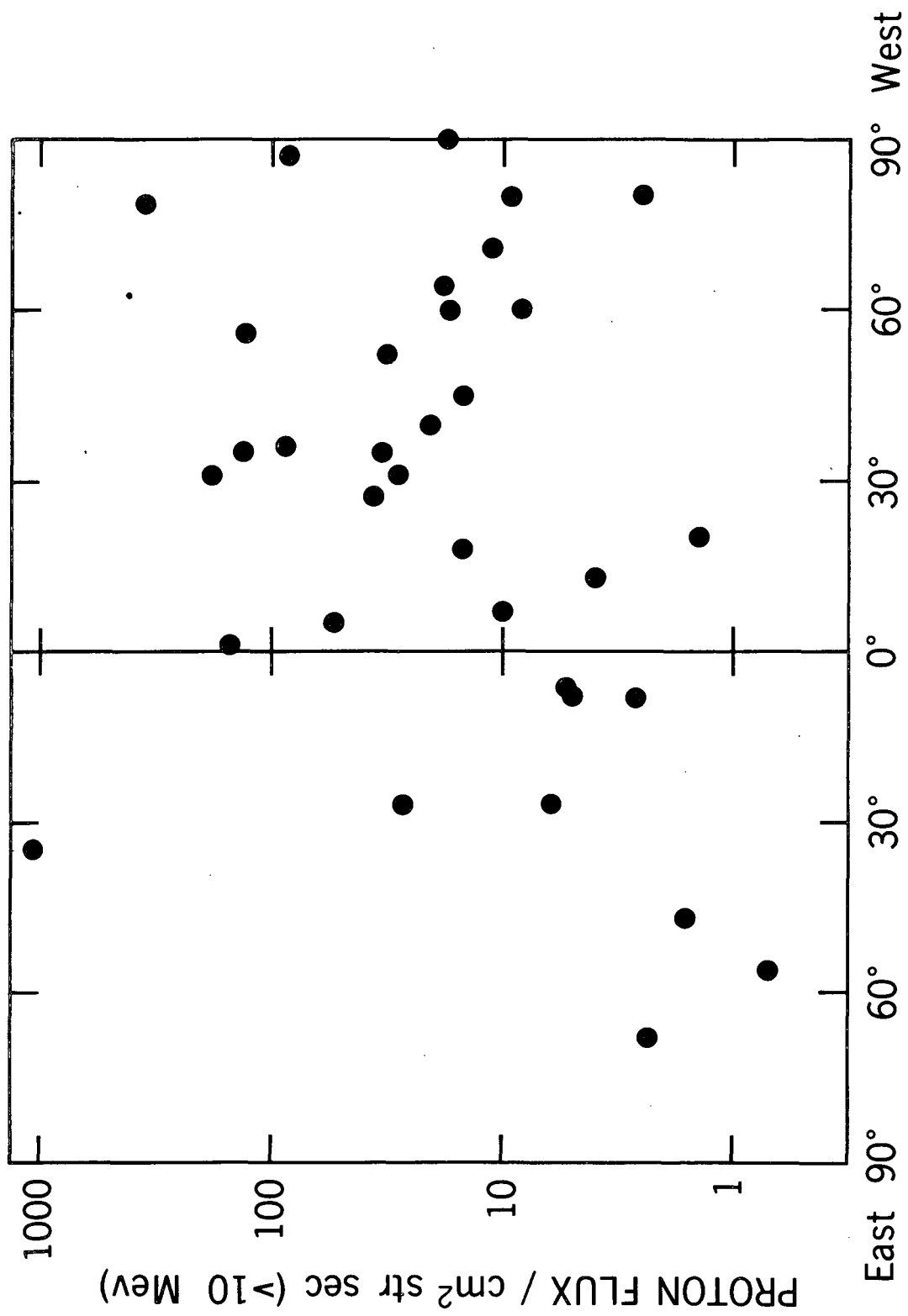


Fig. 1 - Dependence of the proton peak flux on the angular distance from the central meridian of the sun.

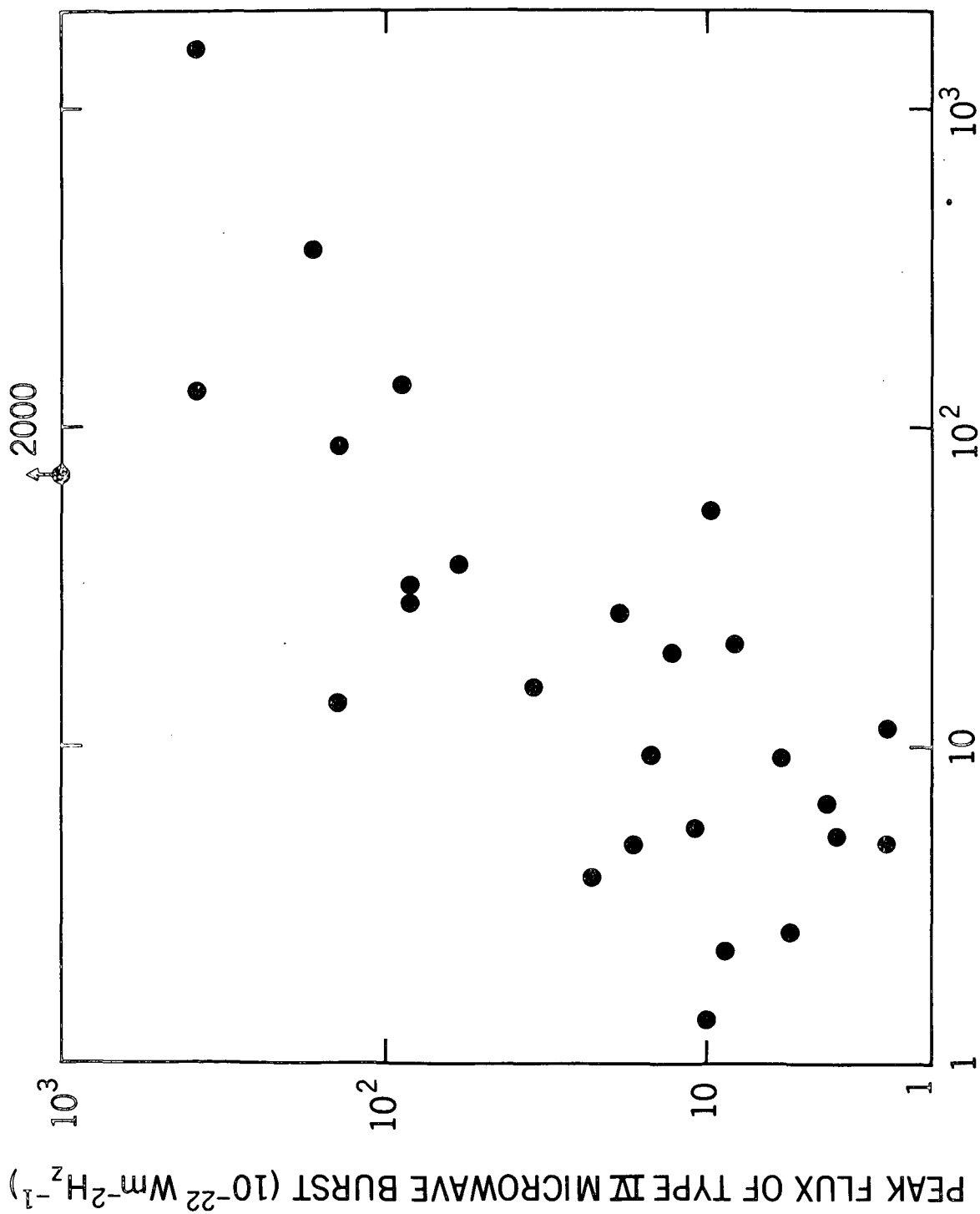


Fig. 2 - Relation between the peak flux of microwave component of type IV radio bursts and the proton peak flux of energy higher than 10 Mev.

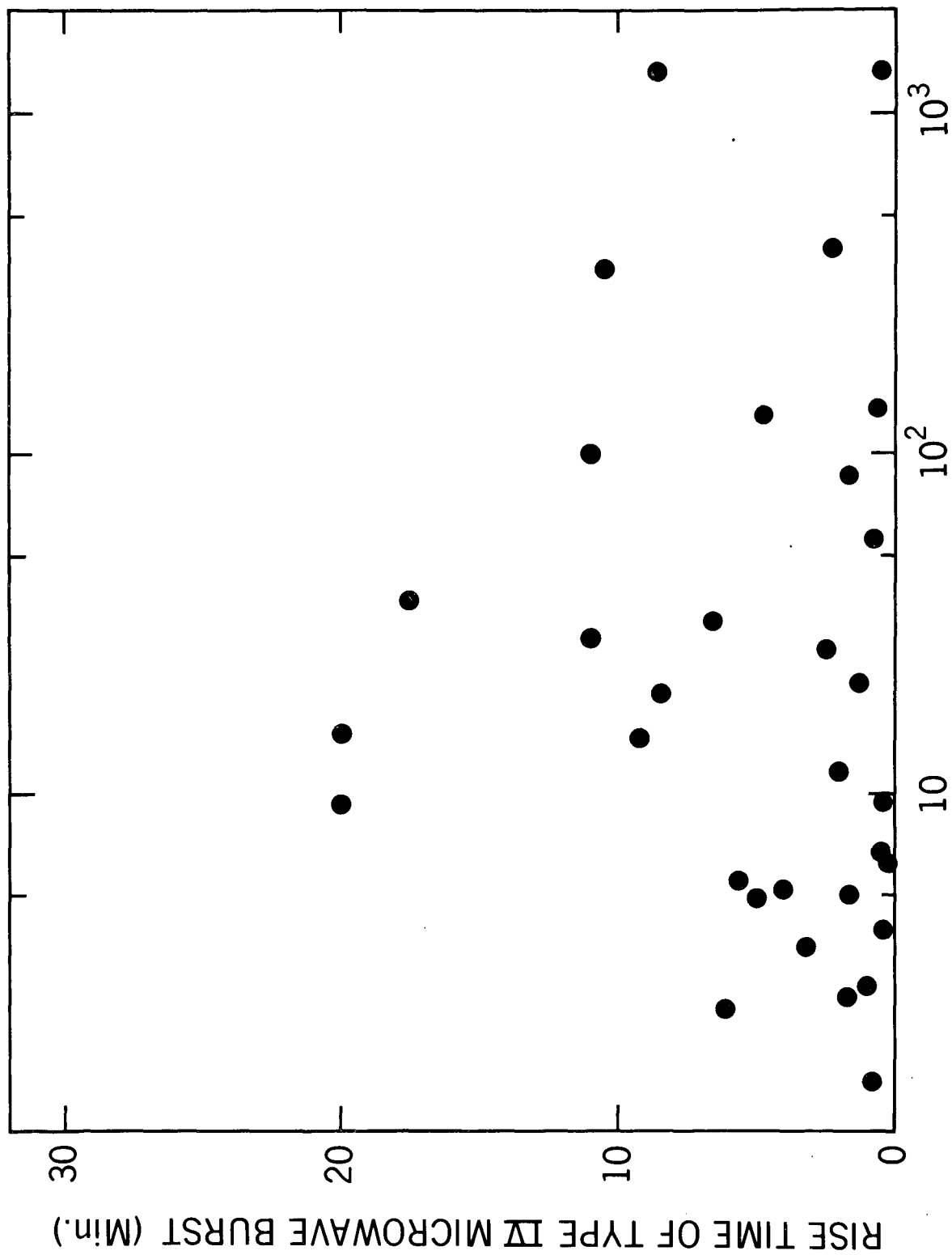


Fig. 3 - Relation between the rise time of microwave component of type IV radio bursts and the proton peak flux of energy higher than 10 Mev.